00/12/56

FINAL REPORT

ON

PHASE I

4-INCH ROCKET

INDEX

I HISTORY

A. Proposal

The proposal, as originally presented, called for a leaflet carrying rocket with the following general requirements:

A. Ranges up to 2500 yards.

B. Accuracy ± 50 yards.

C. Field loading.

D. Packing case as launcher.

E. Payload of approximately 22 ounces.

F. To burst, distributing the payload, with complete fragmentation of missile .

G. To have minimum weight as well as maximum ease of use.

H. Low cost of production.

I. Good surveillance properties.

Preliminary studies indicated that a missile with the following features would be most likely to accomplish the above listed requirements:

A. Approximate size 5 x 30 inches.

B. Weights:

Propellant	1.7	lbs.
Payload	1.4	lbs.
Motor	6.0	lbs.
Total	9.1	lbs.

C. Flight characteristics:

1. Spin stabilized.
2. Velocity 100 to 500 ft./sec. dependent upon range.
3. Burning time 0.14 sec.
4. Time to target 22 sec.
5. Angle of elevation 45°.

D. Initiation by electric squib.

E. Propellant: JPN double base.

F. Burster: Black powder.

G. Single train fuse.

H. Multiple motor tubes.

In the development of the item it was anticipated that the features chosen would be re-evaluated as the program progressed and that some modifications would be required.

B. Separation Into Phases

As mutually agreed, the project was separated into three phases. The division of money is shown in an attached sheet in the appendix. By so doing, the entire project was not committed until the unit had been shown feasible in preliminary testing.

Briefly, the phase separation is as follows:

Phase I

A. Mathematical analysis.

B. Study of materials.

C. Static testing of motors.

D. Field Flight Tests.

E. Report.

Phase II

A. Redesign

This will include both the overall design and the component parts, such that production in quantity can most easily be accomplished.

B. Model construction.

C. Static and flight tests.

D. Possible redesign to correct undesirable flight characteristics.

E. Report.

Phase III

A. Final design.

B. Manufacture of large lot.

C. Final flight testing.

D. Preparation of Range tables.

E. Report, including drawings, specifications, instructions and range tables.

In Phases II and III it will undoubtedly be necessary, as it was in Phase I, for the work to be in a fluid state, rather than to proceed in a set, crystallized pattern. The flow of work is such that it is sometimes difficult to proceed in a stepwise fashion since some steps require much more time than others.

C. Methods of Attack

Initial investigation involved mathematical analysis of the problem in order to translate rocket theory into the desired motor design. From this consideration, coupled with the aims of the project, the multitube, spin stabilized model evolved.

From an understanding of the relationship between grain configuration and grain burning rate, the demands on a nozzle were studied. Preliminary static testing of single steel tube motors offered a means of testing the results of this study and, if successful, this concert could be translated into a workable plastic multitube model.

As the experimental work progressed, it became apparent that the basic design and planning were essentially correct but that an intensive search for suitable construction materials would be necessary. Each component of the rocket evolved from a study of the requirements upon that particular part, followed by an experimental period wherein that part was brought to a status capable of withstanding the stresses applied upon it. Frequently, the increased strength of one component brought out a weakness in another part, which in turn had become the "weakest link of the chain". The limited strength of plastic materials, plus the intrinsic difficulties involved due to the requirements of the item, left little margin for a safety factor of strength in any component of the rocket.

II PRELIMINARY DESIGN CONSIDERATIONS

The design characteristics of this rocket were chosen in accordance with the performance requirements outlined in the proposal. An incremental charge loading system was chosen as the logical answer to the multiple range requirment. This might have been accomplished in a conventional rocket design but the problem of field loading, closing and sealing a conventional design appeared difficult. A multiple motor tube arrangement was conceived which might be field assembled and sealed with considerably more facility than with a single large motor tube. The difference in these two cases is that the stress to be encountered by the large closure would be several times as great as the stresses distributed among several smaller closures. However, the multiple tube arrangement introduced the problem of having all the individual rocket motors operating alike. If they did not ignite at the same time and simultaneously produce the same thrust, then greater dispersion would result. One method of insuring identical performance was the interconnection of the motors to achieve equalization of the gas pressures. This also aided the ignition because if one motor failed to ignite, the hot gasses from the other motors would immediately flow to that motor and ignite its grain. While this system of operation was novel, it was not unprecedented. Interconnected individual motors have been used where thrusts in different directions were desired to produce torque. Simultaneous ignition and pressure equalization were accomplished.

The accuracy requirement led to the decision to utilize spin stabilization since a spinning rocket has less dispersion that the same rocket using fin stabilization. Moreover, the rocket launcher should be as long as possible for the sake of accuracy; launching a spinner rocket might be simpler since the launcher would not have to accommodate projecting fins. In this rocket design, using individual motor tubes, two methods of obtaining spin stabilization were considered. The first method uses conventional canted nozzles oriented in each of the individual motor tubes. The second method appropos to this particular design uses coaxial nozzles in canted motor tubes. Both methods were considered feasible.

The longer a rocket burns after leaving its launcher the greater the dispersion tends to be. The length of the launcher is limited by the practical problems of transportation and handling so it was desirable to have the burning time of the rocket as short as possible. The web thickness and burning rate of the propellant are the two parameters which fix the burning time of the grain. The web thickness was chosen as small as possible consistent with other internal ballistics requirements and simplicity of design. The burning rate depends, of course, on the type propellant used and also on the chamber pressure. The propellant JPN was chosen because it was a well-known, well behaved propellant of ready availability. However, it was anticipated (and later experimentally verified), that the relation between nozzle area ratio and equilibrium pressure in these miniature motors would have values differing slightly from those reported in the literature. The chamber pressure could not be increased to shorten the burning time because of the strength limitations of the materials used to fabricate the rocket.

As estimate of the propellant weight required for the various ranges had to be made for the preliminary design. The weight of propellant determines the burnt velocity which, in turn, determines the range at a given quadrant elevation. To compute the trajectory of the missile, one must know the drag force on the missile which is some function of its velocity through the air. The "vacuum trajectory", which ignores this force is general not a good approximation to an actual trajectory. The use of ballistic tables, which have been set up to facilitate computation of trajectories, requires knowledge of the missile's ballistic coefficient. An estimate of the ballistic coefficient of the rocket was made and the velocity required for the rocket to travel the various specified ranges was obtained from ballistic tables computed using air resistance force proportional to the square of the velocity. This approximation is fairly good for low velocity missiles. Range tables for the final missile design will be prepared from field firing data.

III STATIC TEST PROGRAM

A. Development of Test Equipment

The progress of the project was advanced considerably by the availability of a special photo-recording cathode ray tube oscilloscope, as shown in Plate I. The instrument, which had been built for closed bomb powder testing, was modified to record rocket chamber pressures.

A wall mounted steel adapter head was designed to receive a threaded head end of a rocket motor. The adapter also mounted a Baldwin Lima-Hamilton SR-4 strain gage pressure cell with electrical leads running through the barricaded wall space to the oscilloscope, as illustrated in Plate II. As the squib firing voltage was switched on, a single X-axis sweep was applied to the oscilloscope and this sweep provided a time base for the pressure record.

The signal generated by the SR-4 strain gage was preamplified by an Alinco D.C. amplifier, Model 250. The output from this amplifier was applied to the Y-axis amplifier in the oscilloscope, where it was mixed with a time pulse which calibrated the time base. The shutter for the camera was operated by stepping relays which automatically controlled the progress of the entire sequence. For convenience, the photographic record was filmed by a Polaroid Land Camera mounted on the oscilloscope so that a finished print could be obtained within a minute after the static test was made.

B. Motor Design

Preliminary planning preceding the actual design of a single tube motor, showed a need for motors whose dimensions would be largely governed by the powder grain to be used and whose purpose was to be the testing of motor component parts rather than a test of a motor eventually to be used for flight.

Original requirements called for a completely non-metallic motor. It was anticipated that the small plastic nozzles required in this application would suffer a large percentage increase in throat area during burning. The hot gasses moving at high velocity quickly erode a nozzle even when made of fire resistant materials. For this reason, a progressive grain geometry was chosen so that the ratio of powder surface to nozzle throat area would remain more or less constant.

1. Motor Tube Components

Motor #1, as shown in Plate III, was fabricated to determine proper ignition methods and the variation of pressure and burning time with nozzles of different diameters. The motor, a steel tube with an ID such that an inhibited grain would make a snug fit, was threaded at the head end to screw into the pressure measuring block. A steel nozzle was threaded into the tail end. The grains, shown in Plate IV, were inhibited by encasing them in a cellulose acetate tube, using polyester resin as a binder. Examination of the pictures of the oscilloscope traces resulting from test firings showed that the burning was progressive, as anticipated. Ignition was accomplished by the use of an M1A1 electric squib with a black powder booster.

Motor #2, shown in Plate V, was constructed from a similar steel tube, the tail end of which had a cavity for inserted nozzles of various materials. After determining the proper throat diameter, shots were fired using a nozzle made of polyester resin. The results of these shots showed that the disadvantages of an eroding nozzle could, in some degree, be cancelled by a progressive burning grain. Polyester nozzles proved to erode too rapidly, however, so a search was initiated to find a more erosion resistant material. Among the materials tested were paper phenolic, cloth phenolic, epoxy resin with and without glass fiber, aluminum and brass. The most suitable nozzle material for use with a single perforated, inhibited grain proved to be Catalin, a type of cast phenolic resin. This material was used throughout the portion of the test program concerned with inhibited grains. The trap used in all these tests was a 1/4" long cylinder of the 5/8" x 3/4" cellulose acetate tubing used to inhibit the grain.

Another motor, shown in Plate VI was designed with a steel head which threaded into the pressure block, into which could be inserted a 3/4" x 7/8", grade FF-55 Formica glass fiber tube. The tube was attached to a steel tail piece which had an inserted nozzle. "O"-rings sealed each end of the tube and the whole assembly was held together by three 3/16" bolts. This plastic substitute for the steel motor tube was tested and was found to be completely satisfactory for pressures as high as 3,000 psi.

2. Integration of Components For Multitube Motors

The use of a multitube motor provided a means of loading incremental charges for incremental ranges. As originally conceived, this might be accomplished by snapping in only those tubes and charges necessary, using some type of quick disconnect fittings. At the same time, this provided a way of keeping the ratio of propellant surface to nozzle area a constant, since each tube would contain its own nozzle and charge.

In such a motor, it would be necessary for individual motor tubes to operate at the same pressure, otherwise stability and accuracy would suffer. Thrust on each tube must be of approximately the same mannitude and for the same duration. Should one grain burn out before the others, a turning moment would be induced on the rocket. By constructing the motor with a connecting chamber common to all tubes, these difficulties can be avoided. In addition, sumultaneous ignition is rendered easier, since the igniting charge may be placed in the common chamber.

Following the determination of proper ratio of powder surface to nozzle throat area by the use of single motor firings, a multitube motor was constructed. This consisted of an aluminum head plate to receive up to 15 glass fiber-melamine tubes with a central steel connecting bolt leading to an aluminum tail plate which received the tail end of each tube and had a Catalin nozzle insert for each tube. Threaded to the outside of the head and sealed to it with an O-ring, was a cavitated cap which was connected to the pressure measuring block by means of an adapter. The cavity thus interconnected all the tubes so that pressure equalization could be achieved. Several successful tests were made with this motor, each producing a satisfactory pressure time curve. It was felt that the basic construction was suitable, so design was begun on an all plastic model.

C. Design of Multitube Motors

1. Screw Cap Type

Following the successful testing of the multitube aluminum unit, motors were fabricated wherein the aluminum head and cap were replaced by plastic parts. The first attempt involved the use of a cloth phenolic material known as Celeron for the head and cap, which were threaded together at the periphery of the head plate. The tail plate was made from Catalin, a type of Bakelite, into which were drilled six nozzle holes. Each hole was counter-bored to receive the tail end of each of six Formica motor tubes which were retained between the head plate and tail plate by a long central bolt. O-rings at the ends of each tube assured a pressure seal. The static firing of this motor shattered the Catalin tail plate, so another was made with the tail plate reinforced by an equal thickness of glass cloth-polyester laminate. When this model was fired, the threaded section of the cap delaminated as shown in Plate VII.

In an attempt to reinforce the threaded section between the head and cap, the central bolt was extended up through the cap so that the head and cap could be held together in the center, as well as by the threads at the periphery. Since the plastic materials used at this time were not strong enough to resist flexure, the central bolt was subject to failure. Other materials tested were phenolic laminated cloth and phenolic laminated paper, but without success.

2. <u>One Piece Head Motors</u>

Another variation in design employed a system by which the head and cap were replaced by a single integral unit. It was essentially the same in principle with a central bolt retaining the tail plate in which there were six sockets for the tube ends, each containing an individual insert nozzle. The head, however, was a single piece with six tube holes which were inter-connected at the center by cross-bored channels at right angles to the tubes. Failures of various types were encountered, among which were bolt failure, delamination of the head material, or complete shattering depending on the plastic used and its method of preparation, as illustrated in Plate VIII. Although this design would be desirable, the method was dropped because it was felt that a strong enough material could not be found within a reasonable time.

3. <u>Nozzle Fabrication and Retention</u>

The use of an inhibited grain, although satisfactory from the standpoint of its pressure time curve, was quite troublesome both in manufacture and in use. In several cases, it was found that inhibitor failure caused high pressures during burning and occasionally a grain would rupture because of the failure. The use of uninhibited grains would be much simpler, but since the burning of the uninhibited grain is approximately neutral, a non-eroding nozzle would be necessary. In several static tests, the use of a steel nozzle and an uninhibited grain proved entirely satisfactory. The pressure time curve had a suitable neutral shape and the ready use of uninhibited grains made this method quite desirable. It was felt that the small amount of steel in the nozzle would not present too great a hazard.

In all the ensuing tests, a steel nozzle was used. The nozzle, which was made as a thin shell with the proper configuration and diameter, was inserted into a plastic sleeve which, in turn, was bonded inside the motor tube with resin. The best material for the sleeve was found to be phenolic laminated paper and a bonding resin, known as Bakelite epoxy ERL 2774, was adjudged to possess the best adhesive properties. A retention ring shoulder was provided to furnish additional resistance to blowout. This combination, shown in Plate IX, made it possible to eliminate the tail plate and the central bolt, provided it proved possible to retain the tubes in the head in some manner.

4. <u>Tube Retention Methods</u>

To eliminate the central bolt which held the tubes between the head and tail plates, it was necessary to find a means of retaining the tube in the head plate. As previously mentioned, it seemed feasible to bond in the nozzles with epoxy resin.

A brass adaptor was made to thread into the pressure block and to receive a tube which was to be held in place with a Truarc retaining ring. A nozzle was bonded into the tail end of the tube. This model and several variations of it made entirely of plastic and with a tube bonded in place, were fired successfully, so work was begun on multi-tube motors of similar design.

5. Two Piece Head Motors

Following the successful static testing of bonded tubes and nozzles, a six tube motor was constructed with a cavitated glass cloth-polyester cap bolted to a head plate of the same material. The head was bored to receive the motor tubes which were bonded in place with Bakelite epoxy resin ERL 2774. Each tube contained in its tail an inserted steel nozzle in a plastic sleeve, also bonded in with the same resin. The grain was held away from the throat of the nozzle by an x-shaped steel trap, variations of which are shown in Plate X. Although there was a tendency toward nozzle blowout, successful static firing was accomplished on this model.

D. Revision of Fabrication Methods

During the early portion of the flight test program, failures of various types were encountered and means of combatting the failures were developed through a gradual process.

1. Cap

To ease the manufacturing process, a two piece metal mold was designed in which to lay-up a glass cloth-polyester cap. The finished piece had the desired diameter and also had a molded O-ring groove and cavity.

Previous caps had their O-ring groove machined into the block. This groove, which cut through several reinforcing layers, weakened the cap at this point and failures were encountered due to delamination. While machining was eliminated in the molded caps, failures were still experienced because of insufficient strength in the plastic, although it was reinforced with chopped glass fiber. Attempts to reinforce the groove with wrappings of glass string and with thin ribbons of metal were equally unsuccessful.

All these weaknesses were eliminated by the process of making a preform. This consisted of molding four layers of glass cloth with polyester in such a manner that the entire O-ring groove and cavity were made from one continuous piece of laminate. This was built up with further layers of the same material to the required thickness. No further failures of the cap were experienced following the adoption of this fabrication method.

2. Head

A metal, two-piece mold, similar to that made for the cap, was made in which to lay up glass cloth-polyester head pieces. Six removable metal pins, each positioning a Formica tube, protruded up through the base, the laminate being formed around the tubes. In this way, the six motor tubes could be molded directly into the head. However, this method was abandoned because of insufficient connective strength between the center and the outer area, which caused a type of failure known as "star blowout", as shown in Plate XI. Another type of failure was experienced in models which were fabricated with tubes potted into the head plate. The bond between tube and head was not good and one or more of the tubes were blown out due to the bond failure. The same mold was used without the pins to lay up solid discs of laminate with the glass cloth to resin ratio maintained as high as possible. The solid discs were then bored at the desired angle and direction to receive the tubes, as shown in Plate XII. Few head failures were experienced using this type of construction, although it proved necessary in designing the tube layout to provide a web between holes of sufficient thickness to withstand the sudden stresses applied during firing.

3. Tube Retention

The method described in Section 2. above of bonding tubes into tightly fitting holes with Bakelite epoxy ERL 2774 worked very well for the short range models. With the advent of the long range model, the need for several modifications soon became apparent.

Because of the greater length and weight of the tubes and the higher acceleration of the long range model, inertia of the tubes proved to be a large factor in the blowout of tubes. In a sense the motor went forward with the tubes tending to remain in their initial position. To combat this effect, thin walled tubing of lesser weight was used and the nozzles made as thin as possible in order to reduce their weight. The tube end to be bonded in and the holes in the head plate were grooved so that the resin could interlock the pieces. Although little could be done to lessen the acceleration, the nozzles had the largest permissible diameter so that the motor was working at minimum pressure. In most cases these remedies were effective.

4. Nozzle Retention

By using a combination of bonding and a retaining ring shoulder, nozzles were retained without difficulty in the short range models. Due to higher acceleration and inertia effects, the requirement for retaining nozzles in long range models became more severe.

As an aid to better bonding, the tubes were lightly grooved inside and the nozzle holder roughened so as to provide an interlocking bond with the resin. With nozzles as well as with tubes, great pains were taken to achieve the best bonding possible.

IV FLIGHT TESTS

A. A flight area was selected at a location offering a number of advantages for conducting tests of this type. This area has a fairly level, unobstructed flight path of about 3,000 yards. Storage igloos (which are not now used for explosive storage) are placed 420 feet apart in a straight line for the full length of this area, thus providing a convenient yard-stick as well as shelter for observers.

The initial launching rack was improvised from a four foot length of aluminum tubing of suitable diameter, mounted on a wooden stand at an angle of 45°.

The movie camera used throughout the test program was a 16mm Bell & Howell, Series 200. It was operated for the most part at 64 frames/second, to be projected back at a slower speed. It was hoped that in this way, the initial take-off of a rocket and its spin rate could be studied. The camera was placed on the vantage spot of a nearby igloo, at right angles to the test stand.

Since the igniter for the rocket was a M1A1 electric squib, the field firing was done with a magneto through 150 feet of electric cable.

B. Flight Rockets

1. Payload Section

The ogive or nose was made of molded glass cloth-polyester, as shown in Plate XIII. The nose tapered, at about 60°, back to a recessed ledge which fitted to the motor body. The two were cemented together with Bakelite epoxy resin ERL 2774, after which the joint was sanded in order to remove irregularities. The body was made from a length of convolute wound paper tubing, later replaced with 1/16 wall aluminum tubing. This was an expedient selected to provide reusable parts. Also, although the available paper tubes are suitable for the body on short range models, there is a tendency toward crumpling with the higher acceleration encountered in the long range model. Suitable plastic or paper bodies will be developed in the redesign phase of the project.

2. Motor Section

The motor design chosen for use in flight models is the same as that described in Section III D, namely, a two piece polyester-glass cloth laminated head and cap held together with six steel bolts and provided with a large O-ring seal. The glass cloth Formica motor tubes employed bonded nozzles as well as snap rings, and in turn were bonded into the head plate with Bakelite epoxy resin. Toward the end of Phase I, it proved desireable to use five motor tubes instead of six. Since these tubes would be positioned 72° apart rather than 60°, more web of laminate is provided between tubes.

C. Test Results

As mentioned previously, during the development of a successful flight model, a considerable number of failures were encountered because of failure of the O-ring groove. Of the first ten motors flight tested, eight resulted in failures of this nature. The other two motors were made of glass cloth-polyester with canted nozzles instead of canted tubes and were successfully flown for distances of 1,000 and 1,400 feet, respectively.

After the "preform" method of cap manufacture was adopted, no further O-ring failures were experienced. In addition to revising the method of laying up the laminate around the O-ring, it was found that epon laminates used were much more temperature sensitive than the polyester laminates. Most of the later motors were made with polyester which performed much more satisfactorily. During this period, various other difficulties were encountered, such as bolt failure and blown out tubes. However, the same polyester motor previously flown on two separate occasions was reloaded and flown again, this time going 1650 feet. A completely new canted tube model was also successfully flown 1400 feet. The cause of the variation in ranges accomplished by the polyester canted nozzle model was attributed in part to variation in mass ratio from one model to another, as well as to a variation in effective quadrant of elevation. Because of the relative difficulty in producing canted nozzles, this design was de-emphasized for the remainder of Phase I.

Using the same design and with all new parts, three canted tube models were made similar to the model illustrated in Plate XIV and the same canted nozzle model was rebuilt with new tubes. A new launching rack, shown in Plate XV, was made of steel tubing, which increased the stability of the takeoff. The canted nozzle model was flown for the third time, this time to 2100 feet. The three new canted tube models flew as follows:

MODEL NO.	DISTANCE FEET	TIME SEC.
18	1320	10.2
19	1470	10.2
20	1335	9.8

All three units landed within a fifty yard circle and with a relatively uniform flight time. The dispersion is explained in part by variations in mass ratio which existed in these experimental units. From the success of this group of shots, it was concluded that the design of the short range model was feasible and emphasis was placed on the long range model.

The first three long range models were tested, each with six, ten-inch canted tubes and twice the powder content of the 500 yard model. Each of the three had the same cause of failure and from a cause not heretofore encountered. Because more thrust was needed, the long range model had a higher acceleration. In addition, the motor tubes and grains, which were considerably heavier because of the increased length, had a greater inertia. The combination of these two effects resulted in a force or drag on the tubes, considerably greater than that of the short range model. The result of this increased force was that the tubes, sometimes accompanied by the central star, were blown rearward. To combat this rearward force, tubes were obtained having a wall as thin as practicable, the nozzles were made as light as possible, and very careful attention was paid to the method of bonding the tubes to the head. The tubes were spaced as far apart as available space permitted, thus leaving more web of laminate between tubes.

When the above difficulties were overcome, it was discovered that the combination of inertia and pressure was sufficient to snap the six 1/4 steel bolts which were used to hold the head and cap together. Because of the small amount of time remaining, the number of bolts was doubled rather than starting a search for a better closure.

Six new models were made, incorporating the above mentioned features. In addition, a five tube, pentagonal arrangement was used instead of six, in order to provide a greater web between tubes. Although only five-sixths of the propellant charge could be contained, the loss in thrust was partially offset by the decreased weight of the unit. Of the six models tested, two "chuffed out", which was not unexpected since the K_n was made as low as possible for the purpose of keeping the chamber pressure low. Two units blew nozzles and one blew a tube. One model flew 2500 feet in spite of a chuff in midair.

Three new models were fabricated and tested with mixed success. One blew a nozzle, one blew a tube, but flew 3500 feet. The third took off well, went out of sight from the launching area, passed over the head of a forward observer 5000 feet away, and has not yet been found.

Another set of three units was made and tested with very encouraging results. Two of the three models took off well, went out of sight, apparently going their full range. Their landing spots have not been ascertained despite an intensive search of the area by a large group. The estimated range for all three models is approximately 6000 feet, but since the direction of the launcher could have shifted slightly between shots, the landing circle could be fairly large.

V SUMMARY

The division of the project into phases provided for the establishment of the feasibility of a rocket of this nature without committing the entire contract funds. During the course of Phase I, the conception of what constitutes feasibility was gradually revised. Admittedly, given sufficient time and money, almost any requirement could be met. However, in this case, feasibility meant the probable success in meeting or approximating the requirements within the time and money limitations of the contract.

The work in Phase I has established that a rocket made from plastics can be operated successfully. The study has shown that only those plastic materials possessing the highest tensile strength are suitable for use in this rocket. Joints and closures are critical and will require snap-rings of steel or similar mechanical aids. At points of stress, such as in the "O"-ring grooves in the plastic head, it has been found essential to have the reinforcing material follow the contour of the groove in order to obtain sufficient strength. Motors made thus far have been comparatively heavy in view of the requirement that the rocket should be harmless. However, it is felt that this weight can be reduced somewhat through refinements in design to such an extent that this requirement can be fulfilled. One of the objectives of this work in Phase I was to show that the maximum range requirement could be attained by a rocket fabricated from plastic. It was recognized that only a limited number of flight tests would be made during Phase I. It is felt that the few flights which have been made of approximately 2,000 yards are substantially an indication of feasibility as far as the range requirement is concerned. Admittedly, the rockets which were tested were not of the optimum design. It was desireable that these tests indicate the degree of dispersion which could be expected in a final design although it was recognized that greater dispersion would occur in these prototype units which were made on a laboratory basis.

The accuracy requirement has been investigated only on the short range model. It has not been difficult to place short range models into a circle 50 yards in diameter at a range of 500 yards. The azimuthal dispersion at the long range with a production model, using an improved launching system, is estimated to 150 yards.

Time delays were not investigated in Phase I, however, the requirements for a time delay have been estimated on the basis of the successful test flights. It is felt that a time delay which would have no greater variation than one second over a 20 to 25 second burning period would be sufficient. It is believed that the requirement that the rocket burst should occur between 200 and 100 feet in the air is not feasible. However, this requirement is now considered to be too rigid from a practical point of view and that bursts occuring at somewhat higher altitudes might accomplish the desired result.

The specific objectives of Phase I have been carried out. The test flights of the short range unit indicate that the model would successfully meet the requirements as to range, weight, and accuracy. It is believed that the redesign of the present model will result in the attainment of a successfully operating long range model.

COST STATEMENT

Division Into Phases

50X1

Phase I

Fee

Phase II

Fee

Phase III

Fee

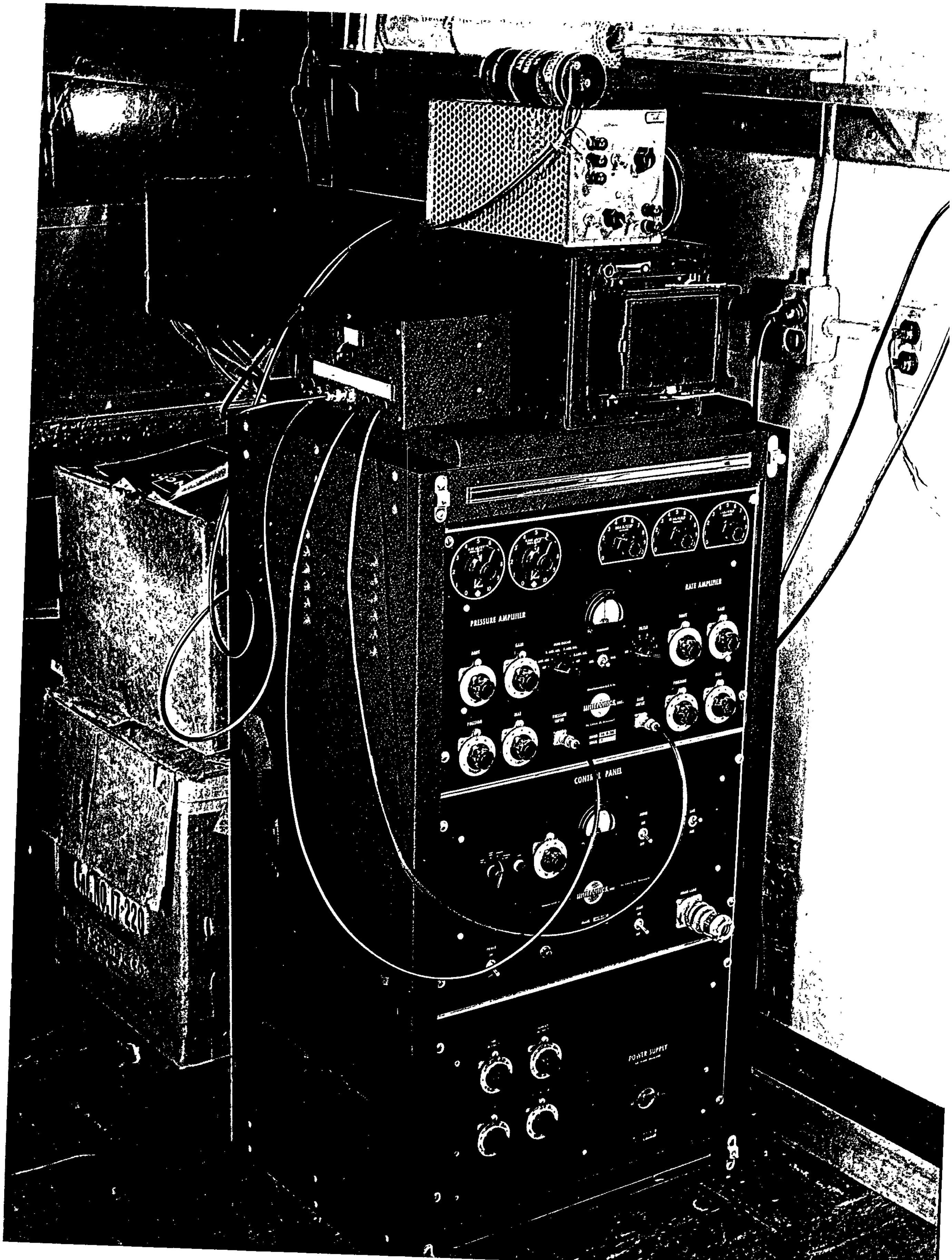
PRESSURE AMPLIFIER
RATE AMPLIFIER
CONTROL PANEL
POWER SUPPLY

PLATE I

Page Denied

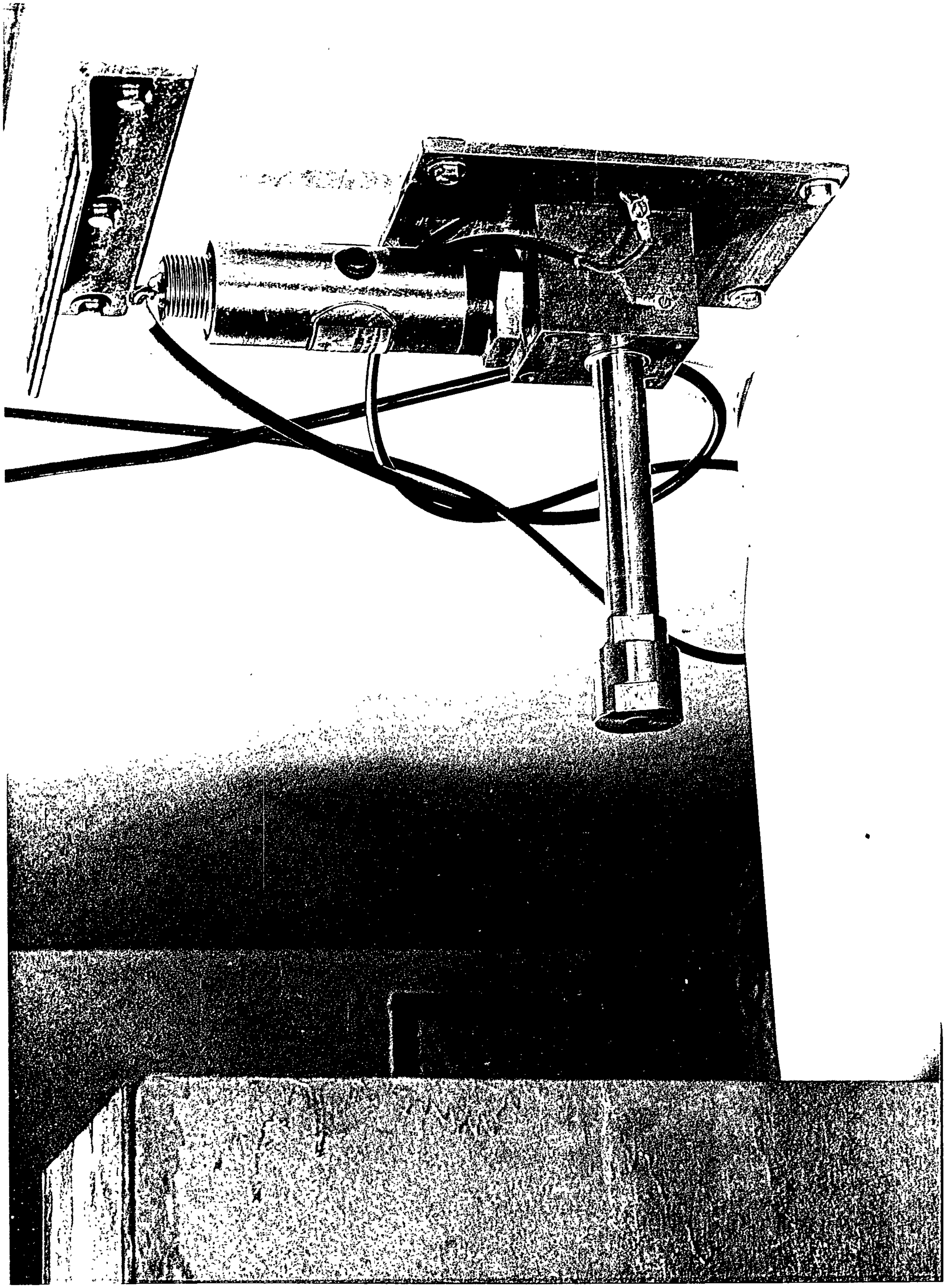

PLATE II

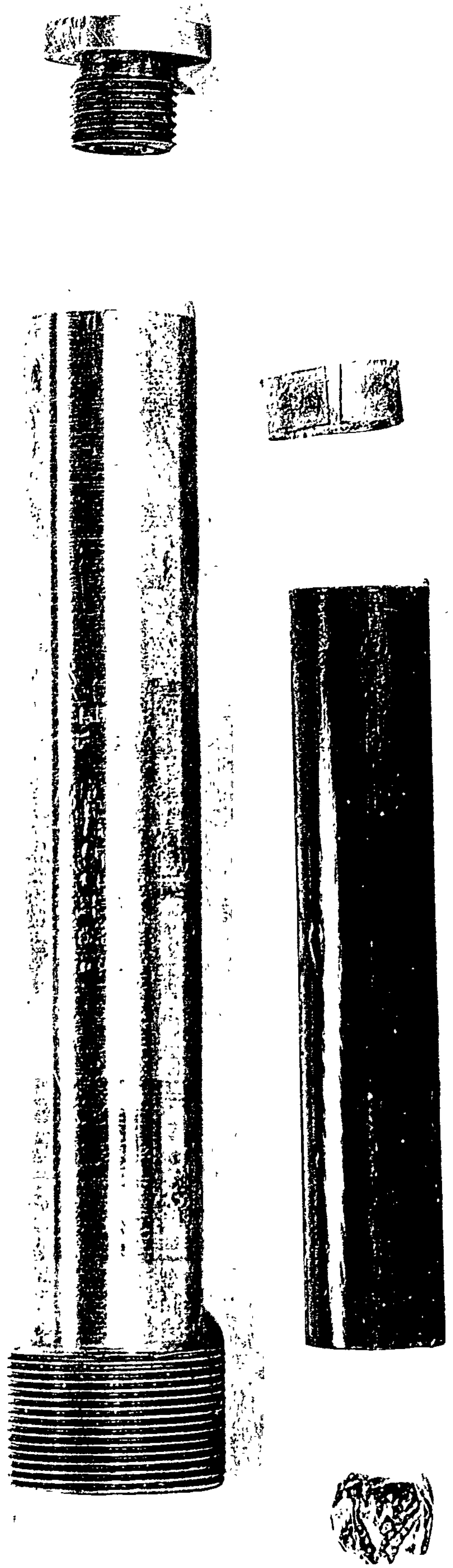

PLATE III

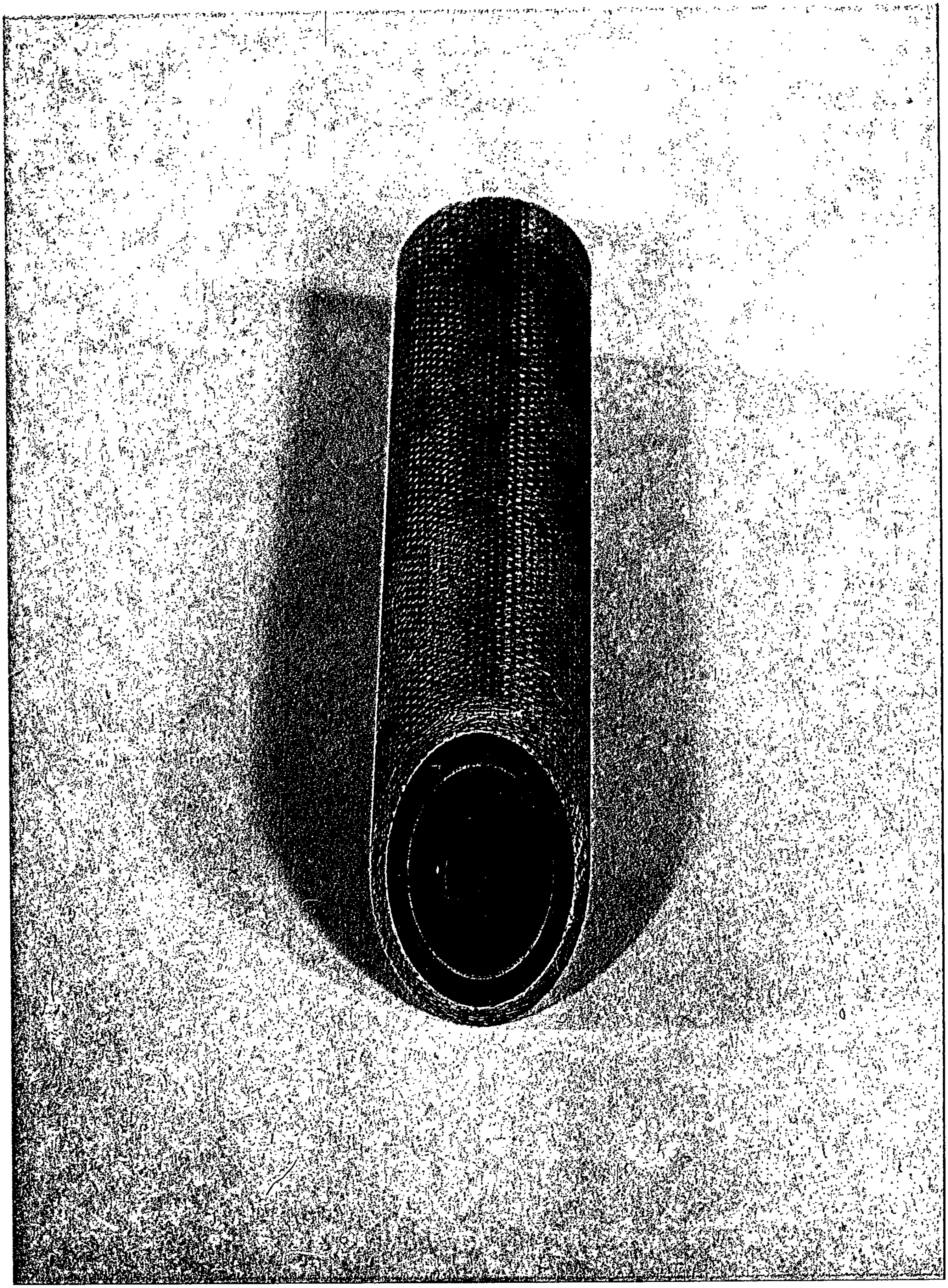

PLATE IV

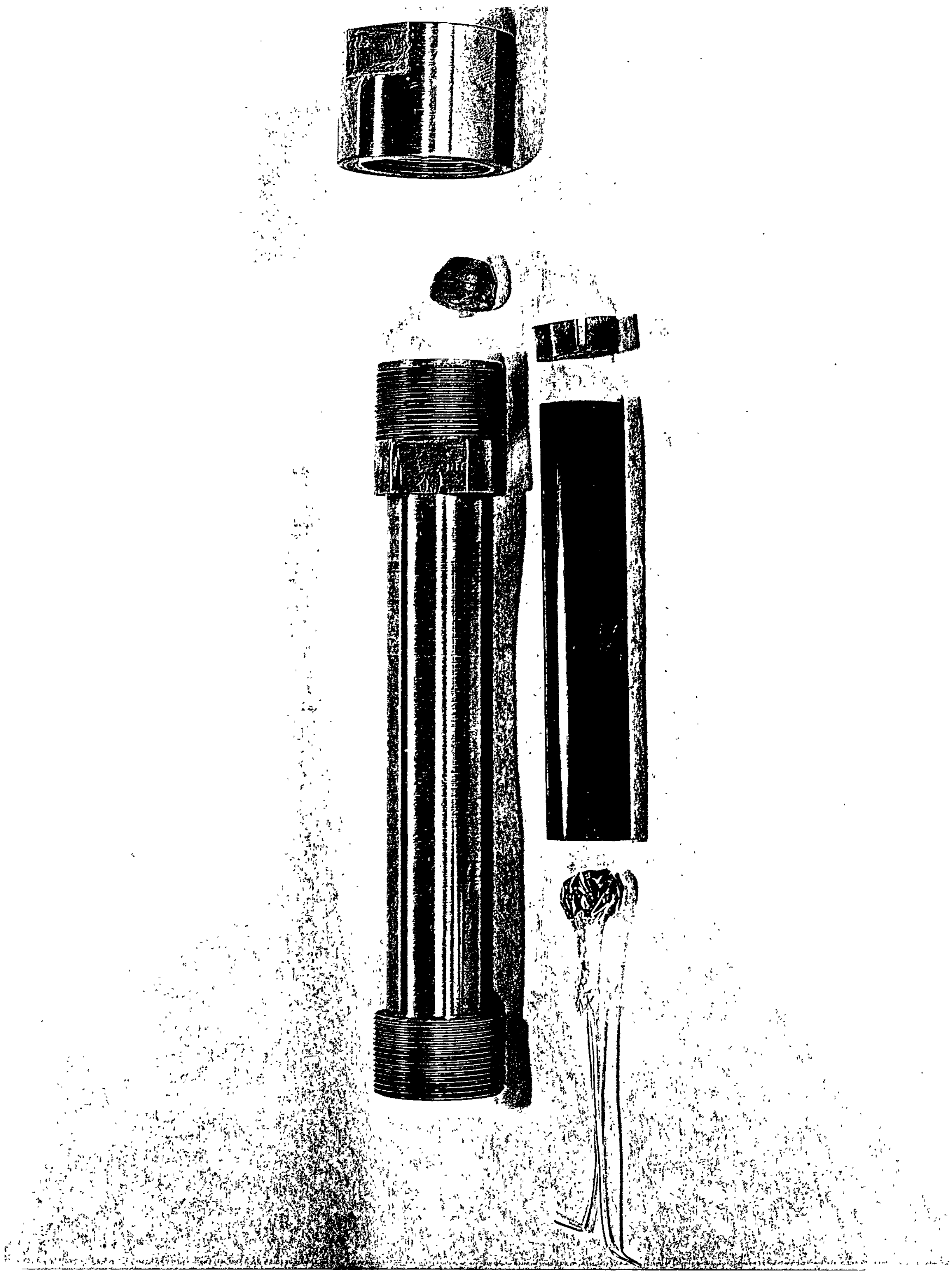

PLATE V

Declassified in Part - Sanitized Copy Approved for Release 2013/08/07 : CIA-RDP78-03624A000900010081-2

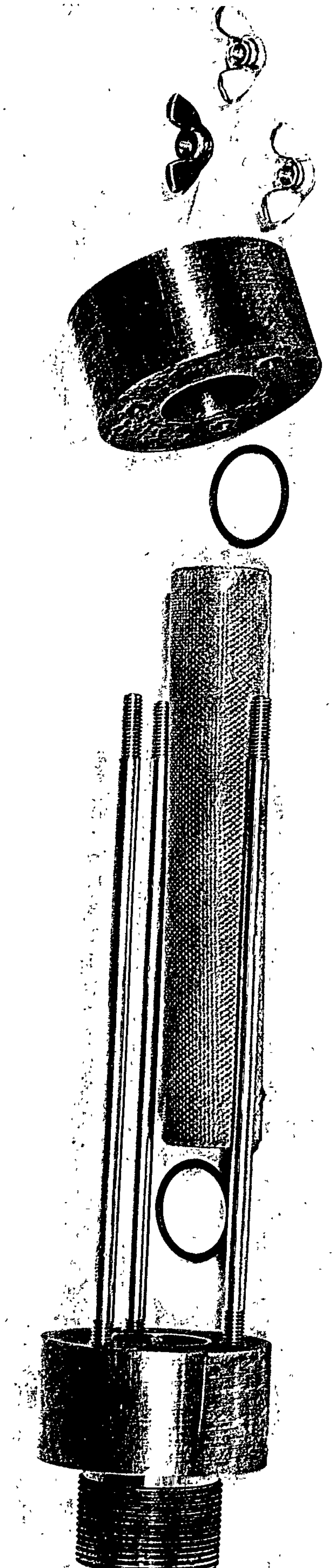

PLATE VI

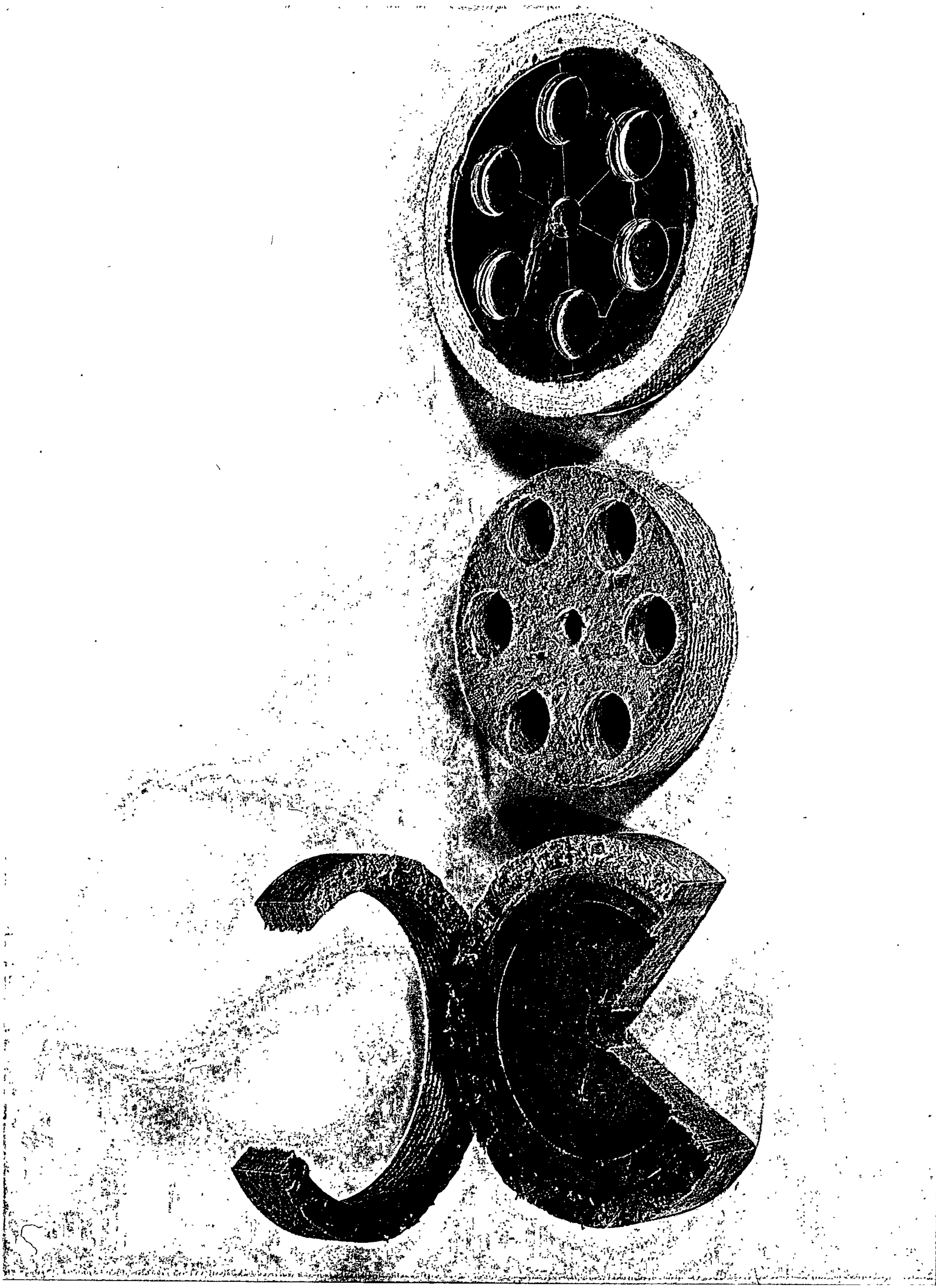

PLATE VII

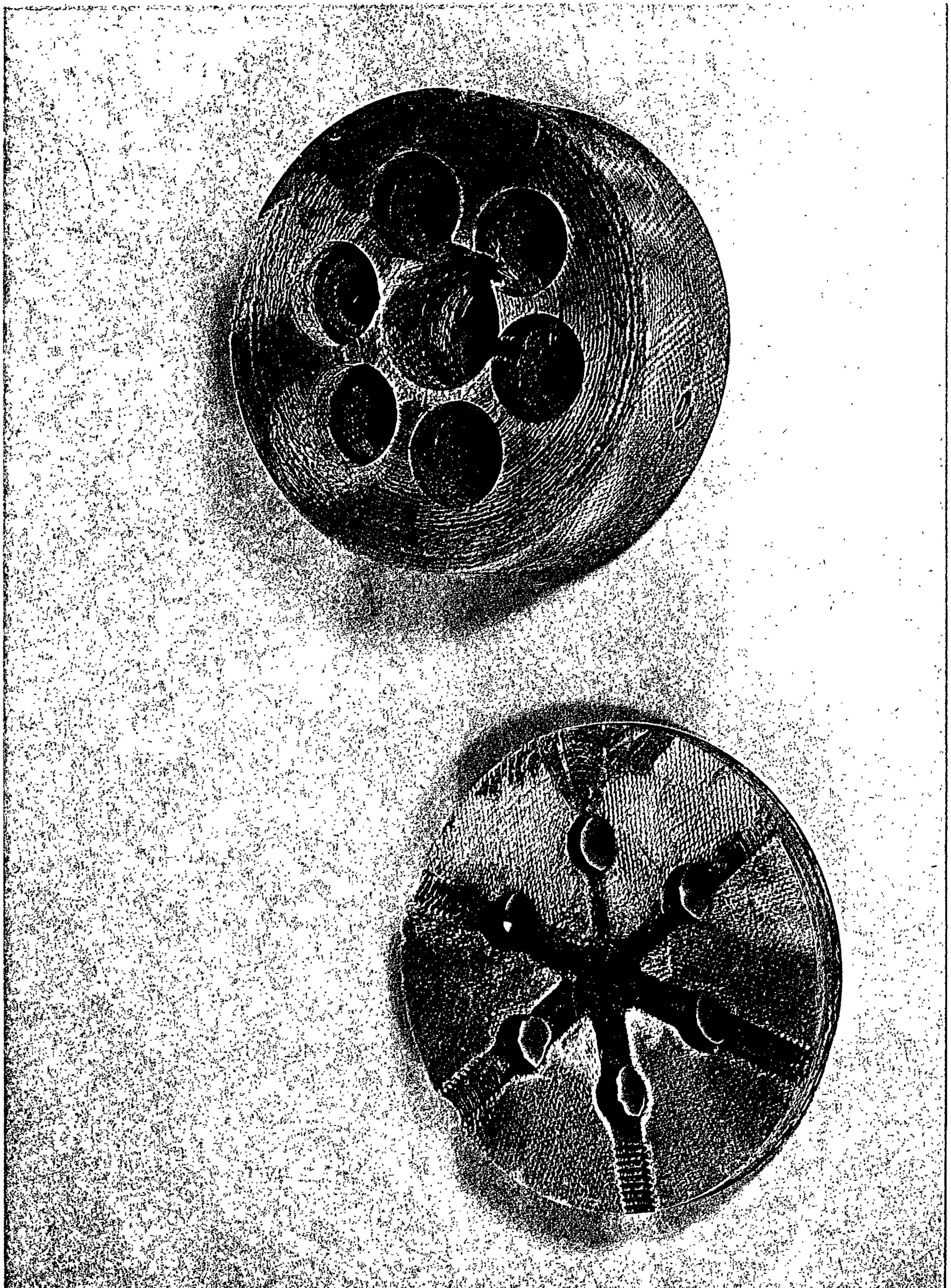

PLATE VIII

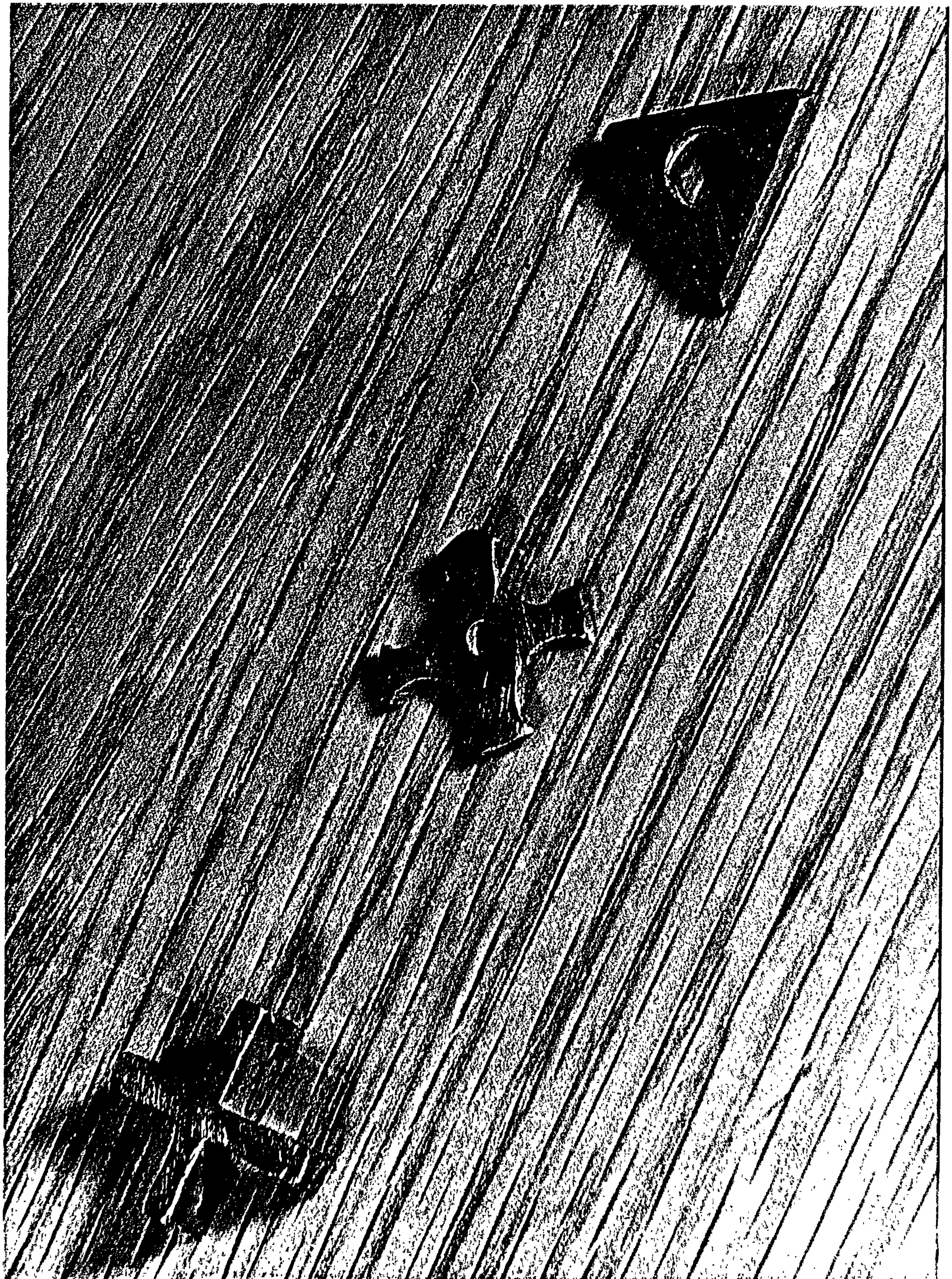

PLATE X

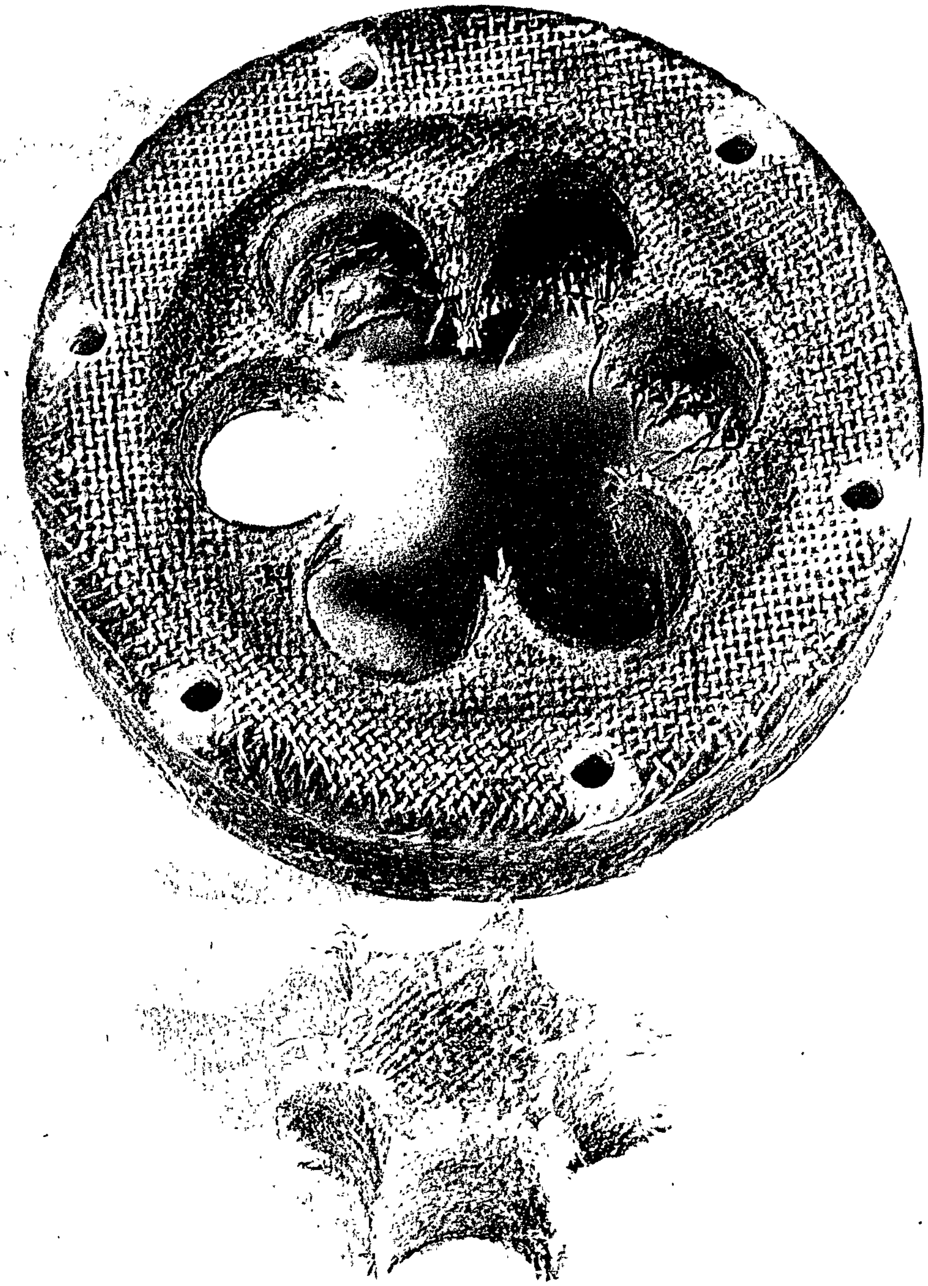

PLATE XI

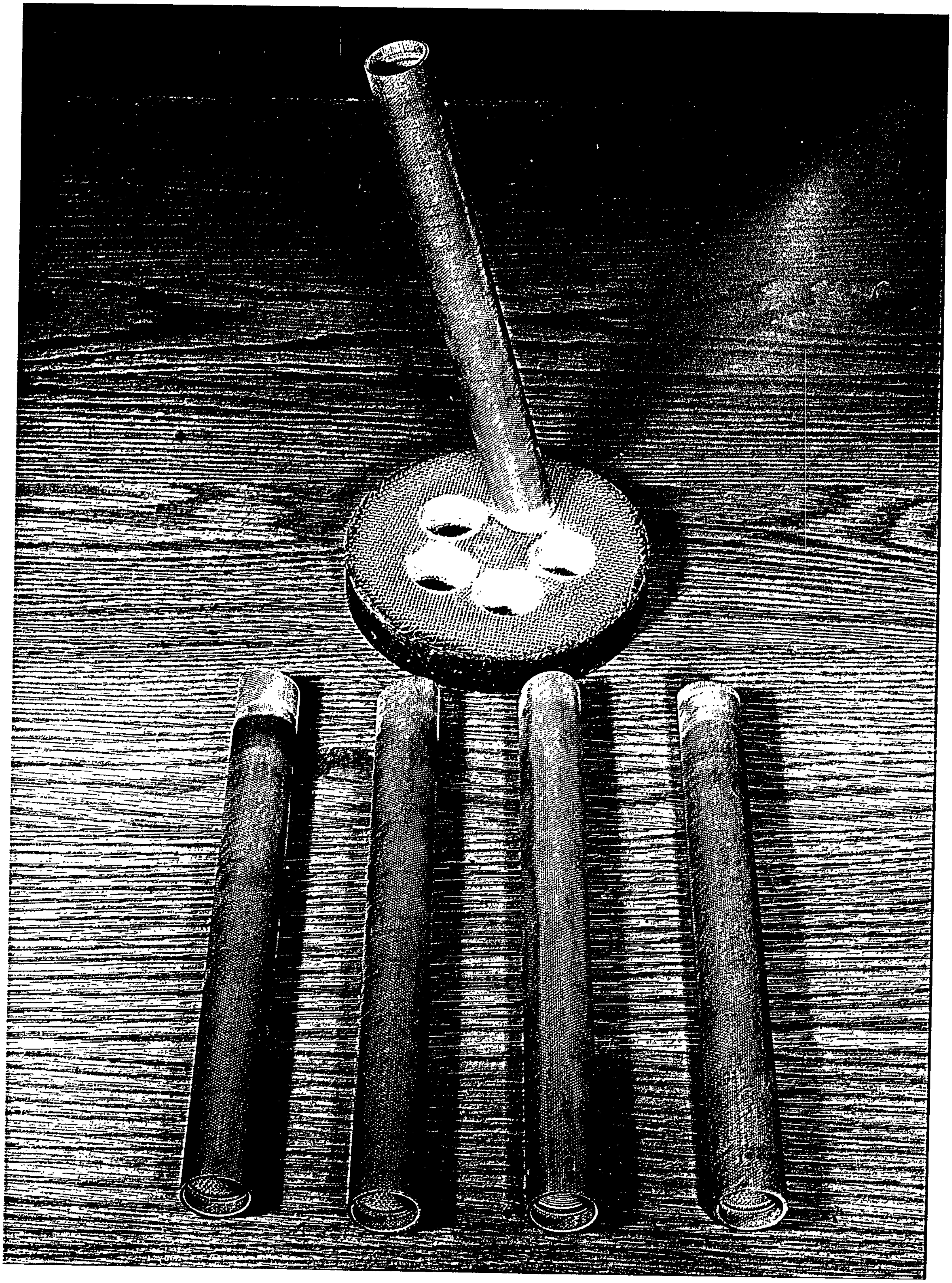

PLATE XII

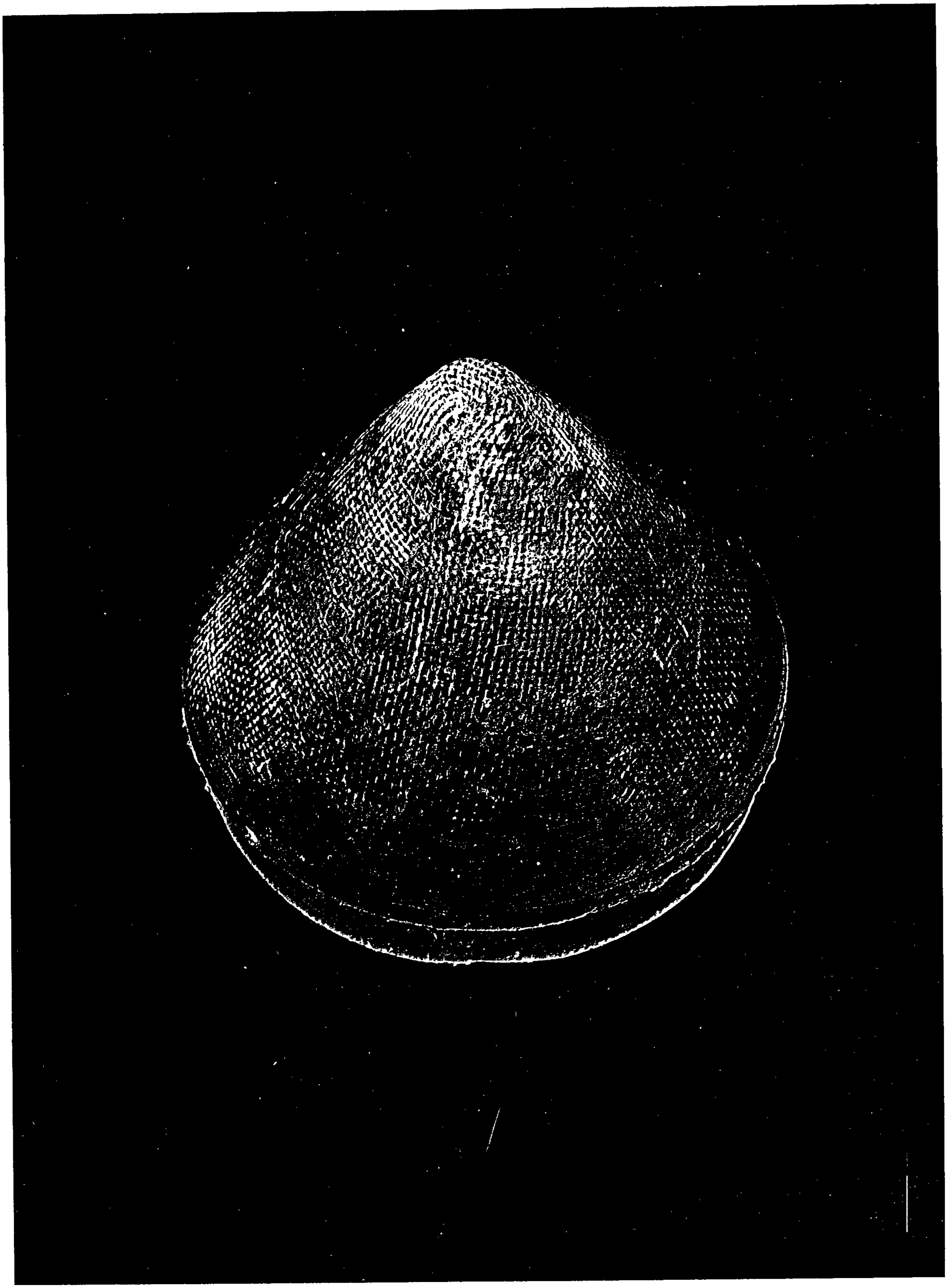

PLATE XIII

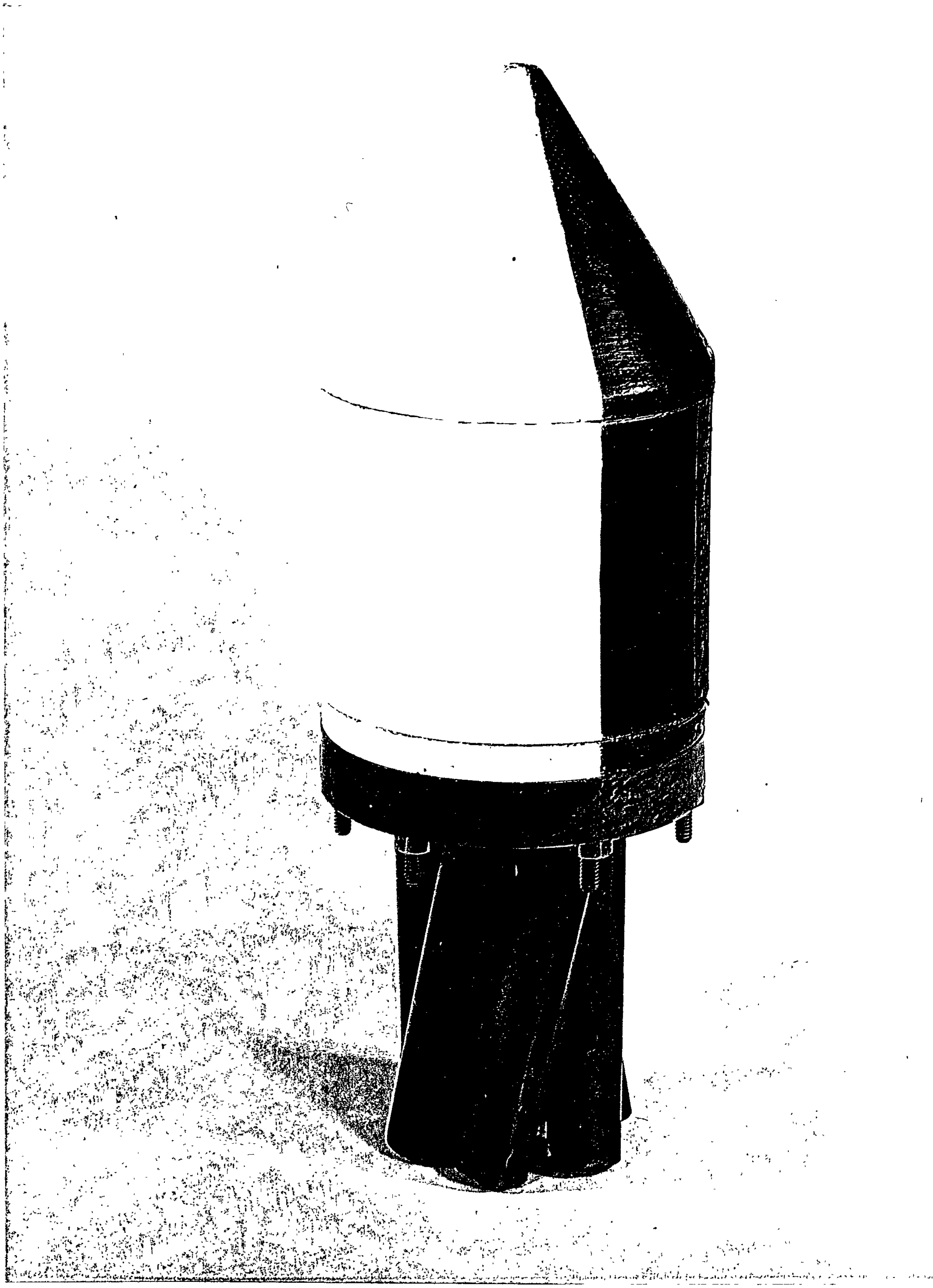

PLATE XIV

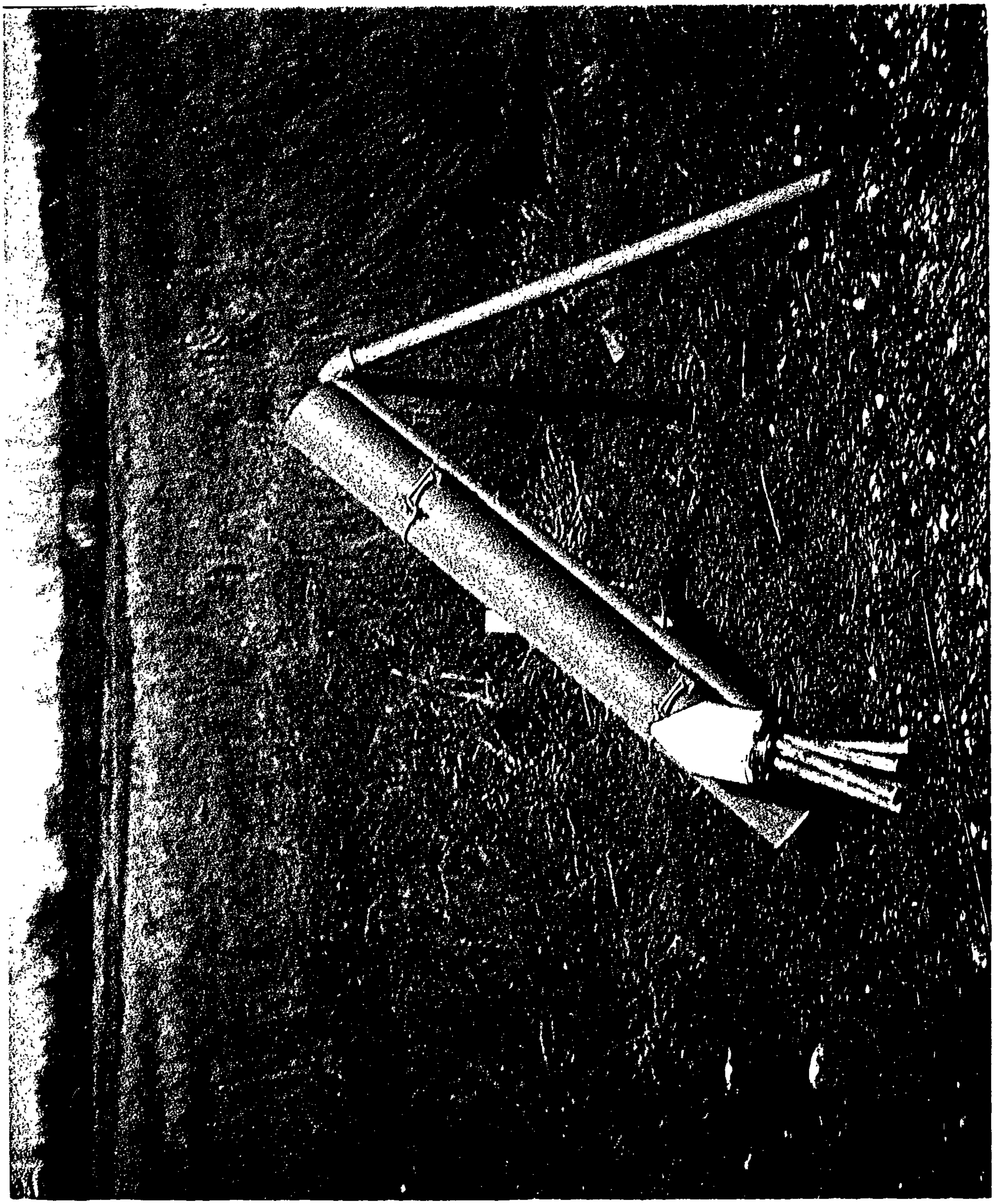

PLATE XV